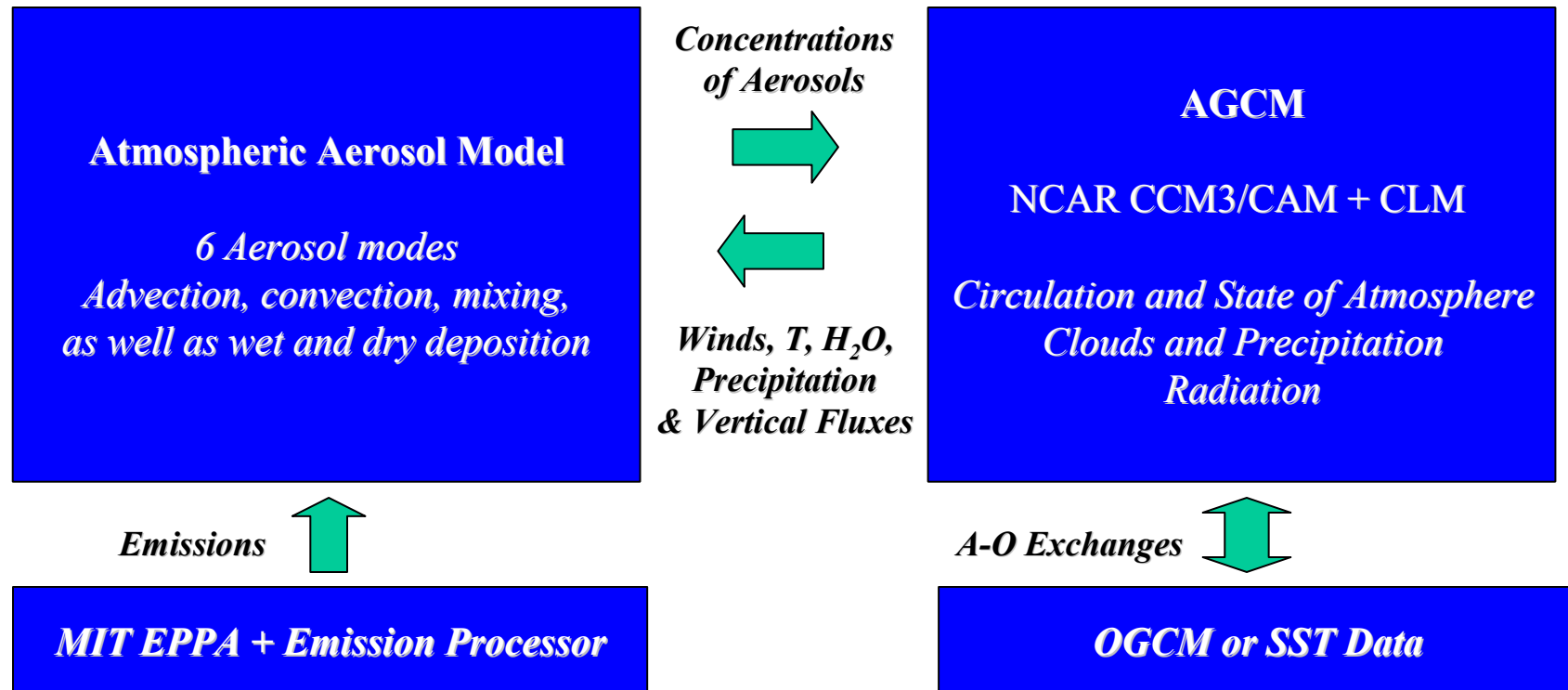


*Regional Black Carbon Emissions
and
Global Aerosol-Climate Model Results*

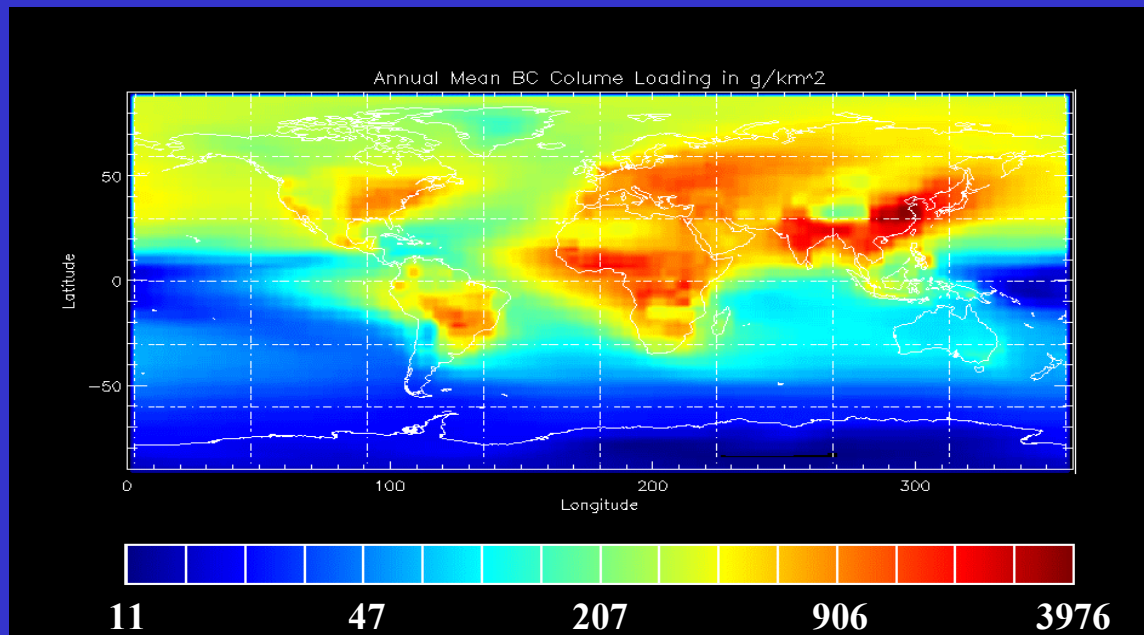
Chien Wang

Massachusetts Institute of Technology

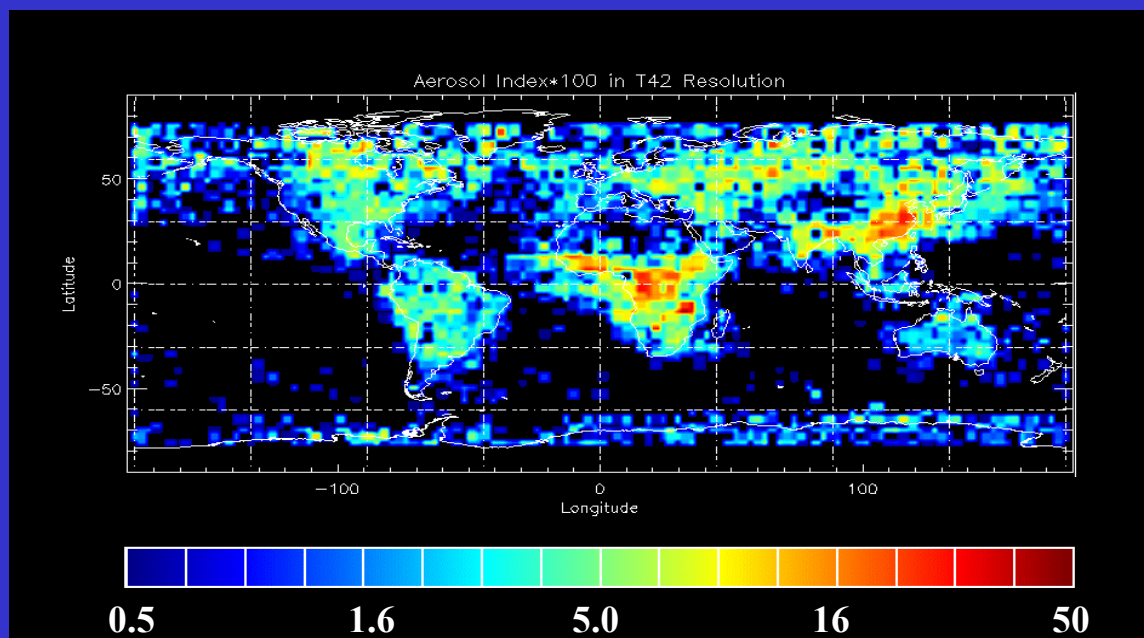
The MIT/NCAR Three-Dimensional Interactive Aerosol-Climate Model



References: Wang 2004; Wang et al., 1998; Kiehl et al., 1998; Boville and Gent, 1998; Mayer et al., 2000; Ekman et al., 2004; Wilson et al., 2001.



*Modeled Annual Mean
BC Column Loading
(in g/km^2)*



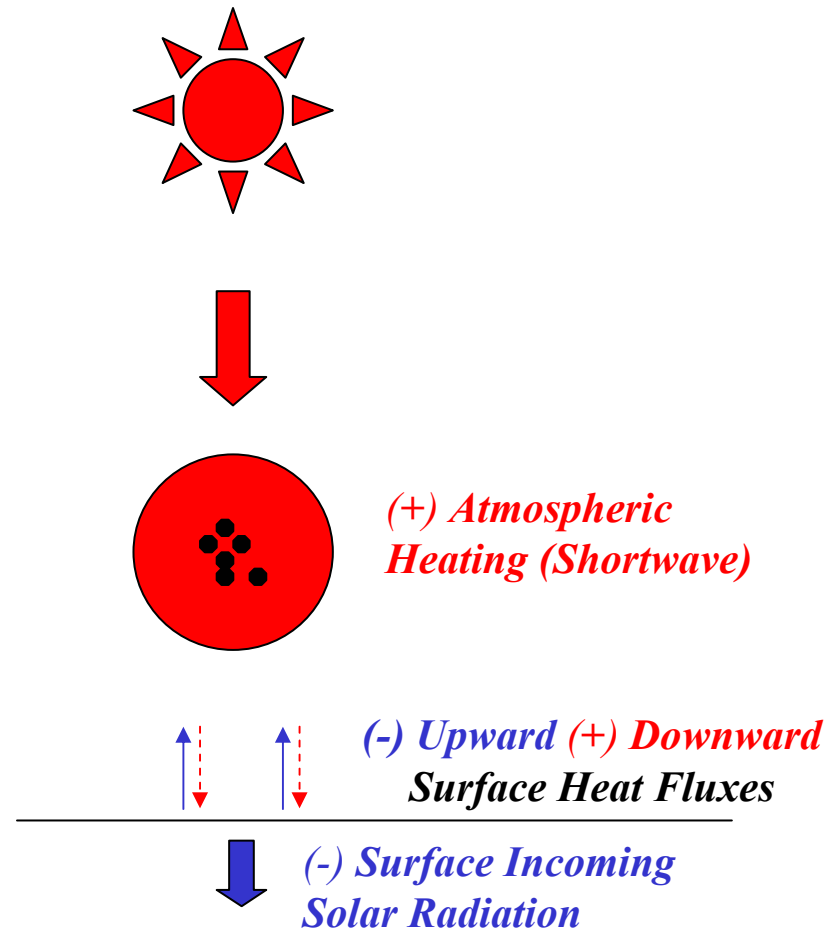
Aerosol Index:
Derived from the monthly
POLDER satellite data
Nov. 1996- June 1997
(courtesy of F.-M. Bréon
and S. Generoso)

Wang (2004)
Note: Colors are in log-scale

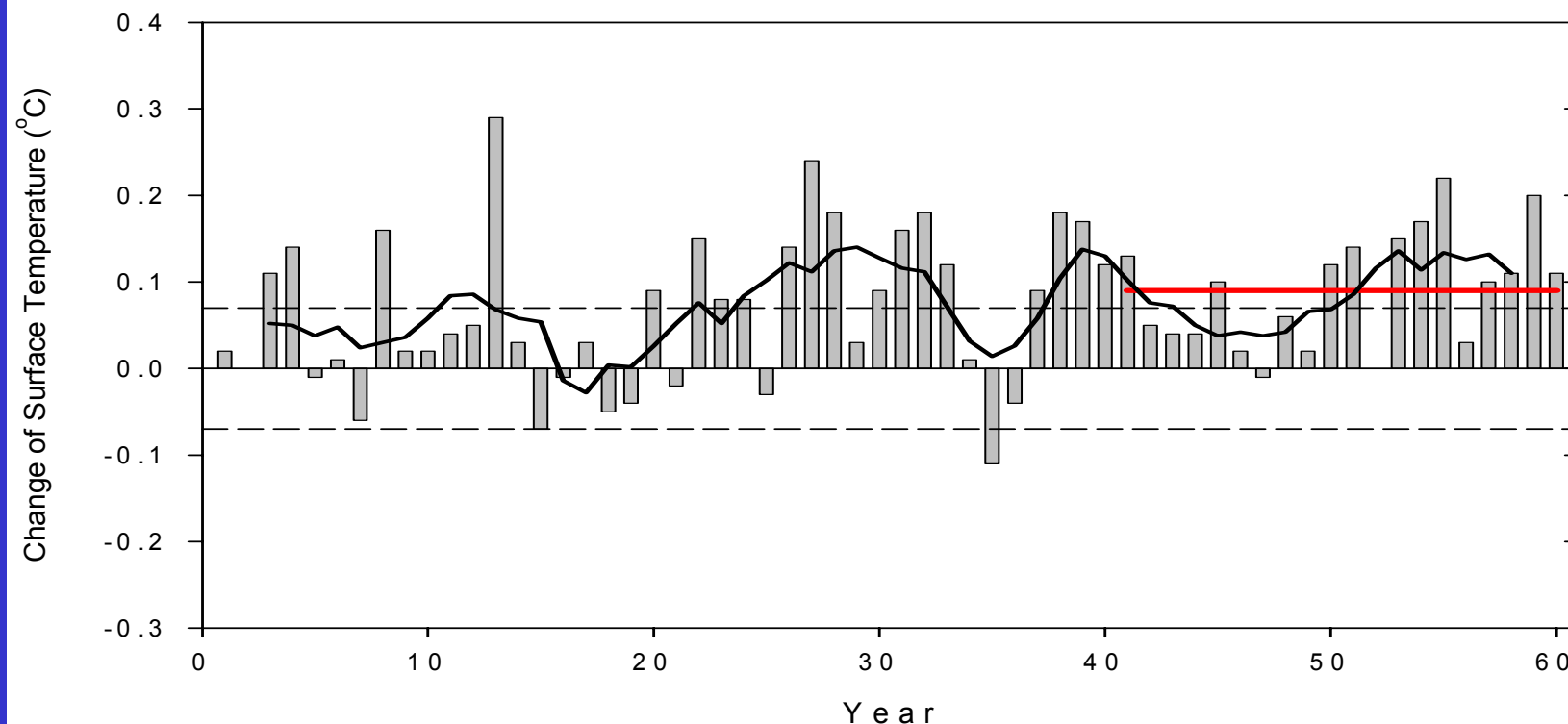
BC Caused “Energy Redistribution”

(Based on the last 20-year means of 2 SOM runs from Wang [2004])

<u>Net Fluxes in W/m^2</u>			
<i>SW</i>	<i>LW</i>	<i>Heat</i>	<i>Net</i>
0.14 ↓	0.09 ↑		0.05 ↓
Atmosphere Net = 0.00 W/m^2			
0.80 ↑	0.31 ↓	0.54 ↓	0.05 ↓
Earth's Surface Net = 0.05 W/m^2			
System = TOA Budget Net = 0.05 W/m^2			



BC Caused Changes in Annual and Global Mean Surface Temperature (Wang, 2004)



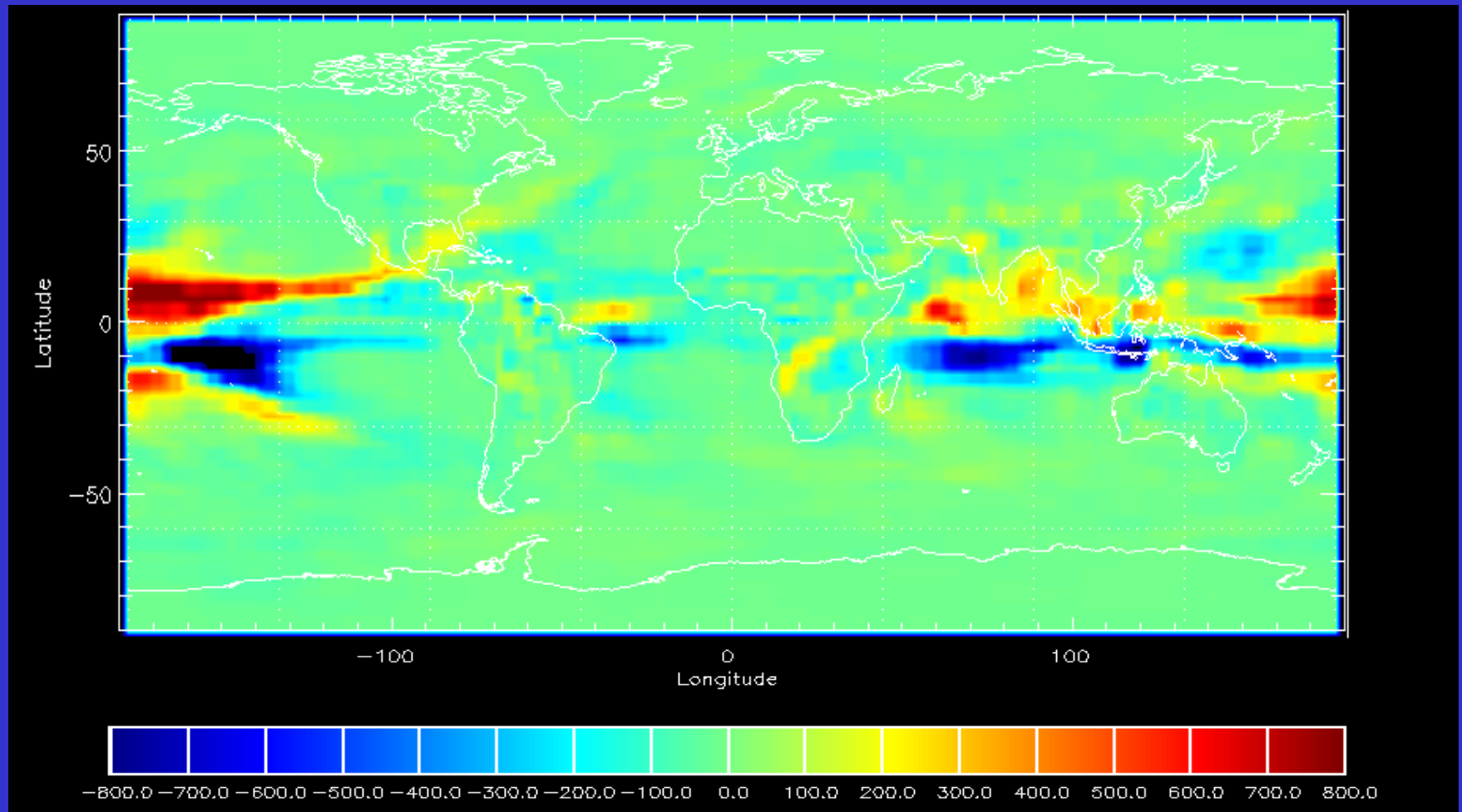
If adopting the concept of “climate sensitivity”, $\lambda = dT/dF$ in $K/(W/m^2)$:

Wang (2004): $\lambda(BC) = 0.26 \pm 0.20$;

Roberts and Jones (2004): $\lambda(4 \times \text{fossil fuel BC}) = 0.56 \pm 0.06 < \lambda(CO_2) = 0.91$;

Also see Penner, Zhang, and Chung (2003).

BC Caused Changes in Convective Precipitation Rate (mm/year) (Wang, 2004)



Also see Roberts and Jones (2004); Chung, Ramanathan, and Kiehl (2002);
Menon, Hansen, Nazarenko, and Luo (2002).

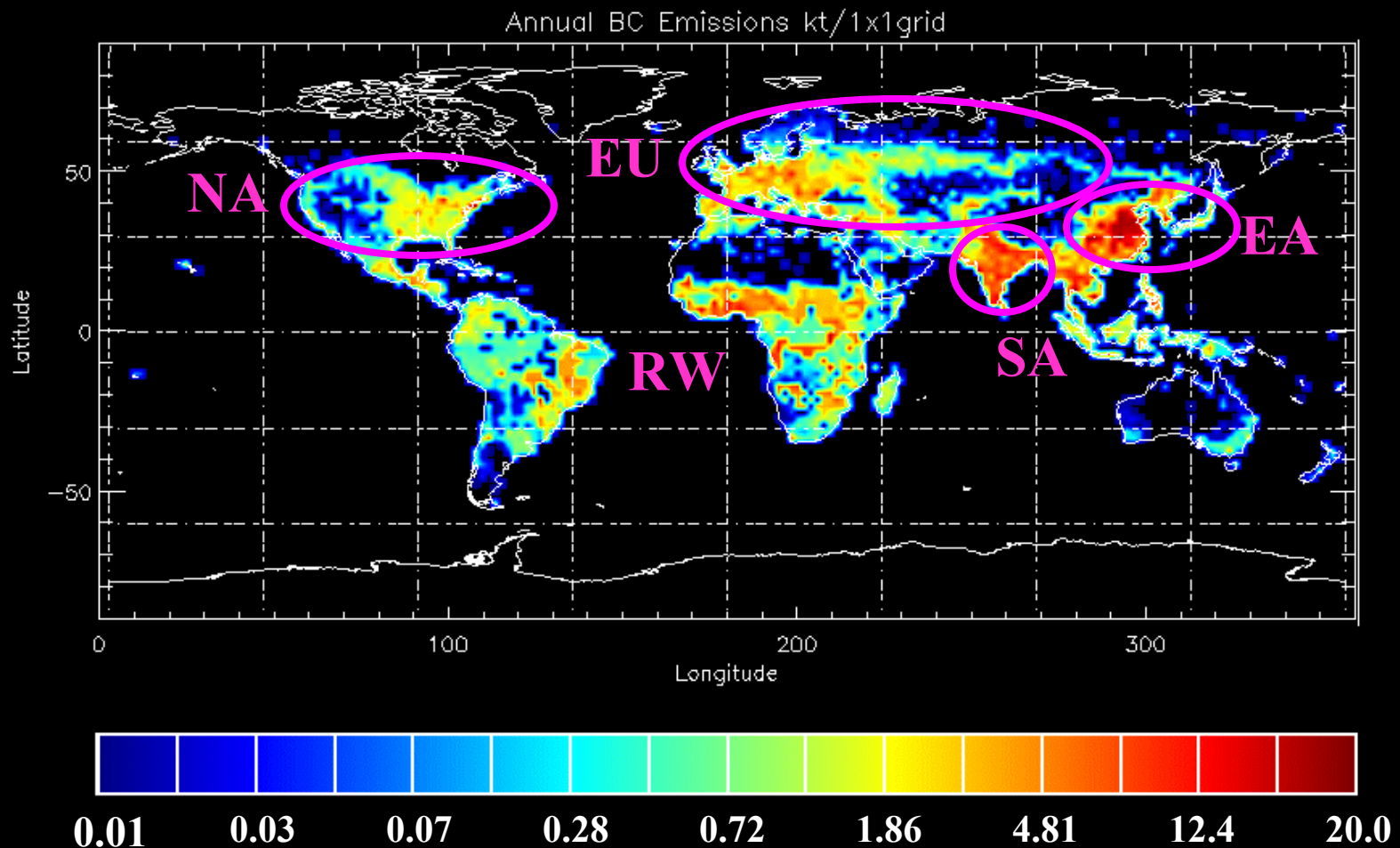
Some Characters of BC and its Climate Impact

- Short lifetime (up to ~ 2 weeks; global mean ~ 1 week) => heterogeneous spatial distributions;
- Modeled climate effects are more significant in regional than global scale (Note: global-wide distributed).

Interesting (academic not geopolitical) Issues

- Are the regional-scale climate effects of BC dominated by the emissions from a specific regions?
- Or, how sensitive are BC caused global climate changes to the emissions from a specific region?

Modeled Input: BC Annual Emissions (~14 TgC/yr) (ktC/yr at each 1°x1° grid; colors are in log-scale)



Numerical Experiment Design

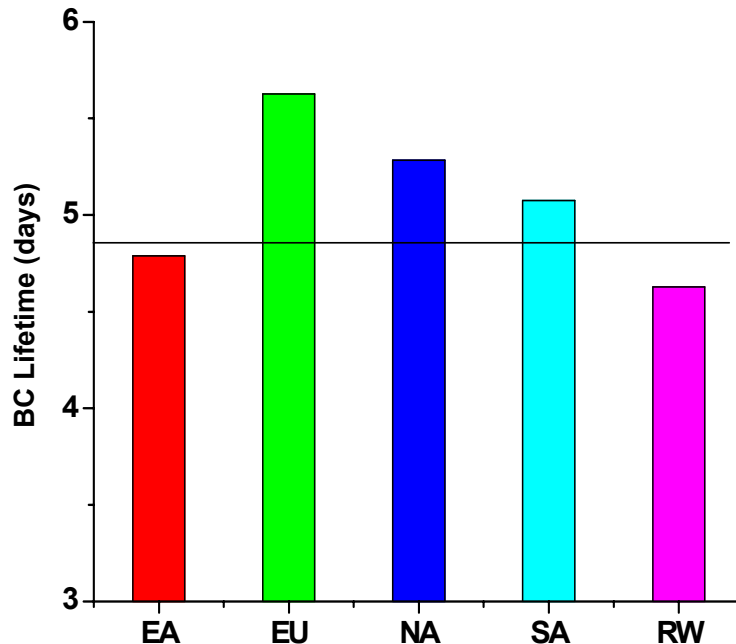
- *2.8°×2.8° horizontal resolution, 18 vertical layers, slab ocean model (SOM) + land surface model (LSM); conventional “indirect effect” is excluded*
- ***Base Set**: 1 run excluding BC interactive radiative forcings but atmospheric evolution*
- ***REF Set**: 1 run driven by emissions from all regions*
- ***Regional Emission Only Set**: 5 runs driven by emissions from only one given region*
- ***Revised Emission Set**: 5 runs driven by global emissions with modified emission at a given region*
- *All runs last 50 years; the last 20-year means are used in analyses; BC effect = Forcing Run – BASE*

Surfaces of Regions with $\geq 50\%$ BC from East Asia (yellow), South Asia (blue), Europe (green), and North America (brown) Emissions

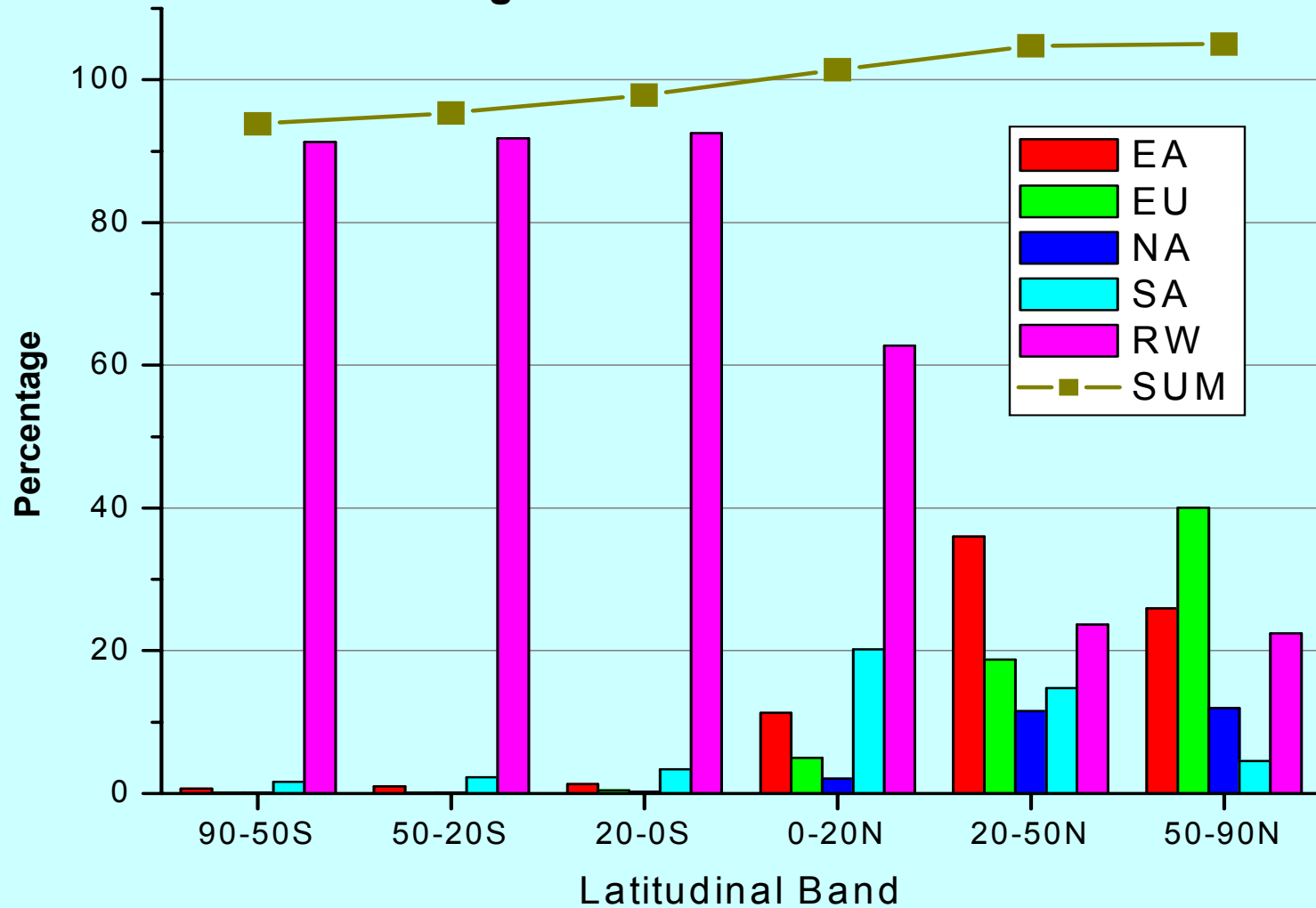
**Average Lifetimes of BC in
Regional Emission Only Runs**

Pressure

Latitude

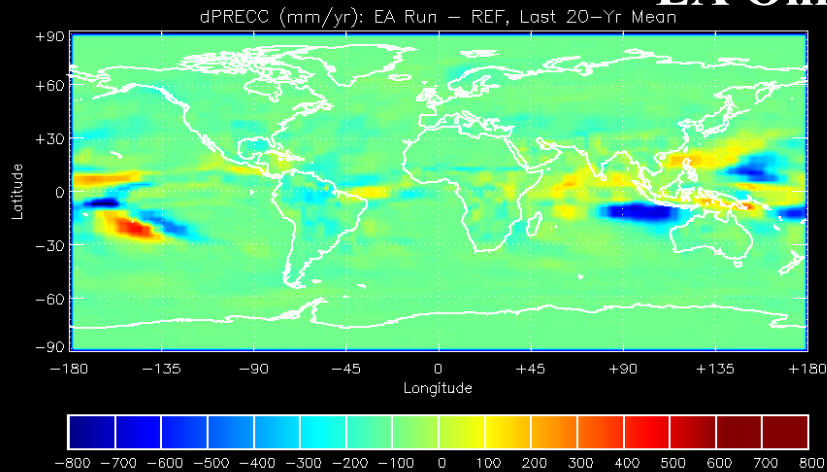


Mean BC Column Loading: Ratios of Regional Emission Runs to REF Run

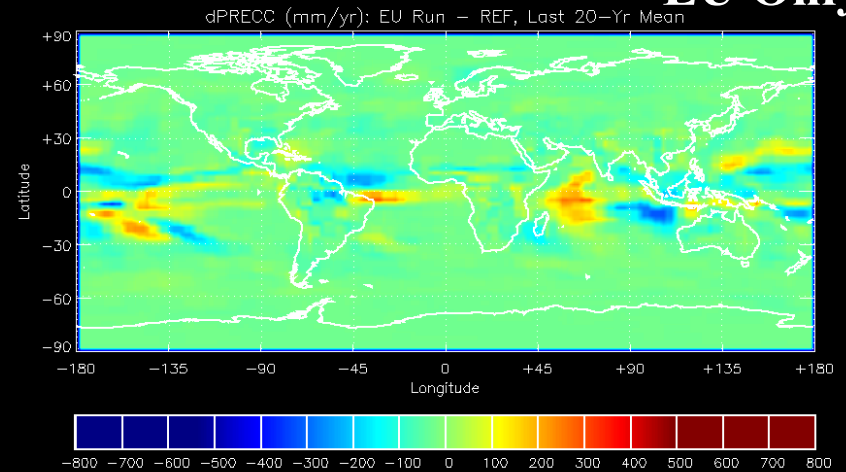


BC Caused Changes in Convective Precipitation Rate: Results of Regional Emission Only Runs (mm/year)

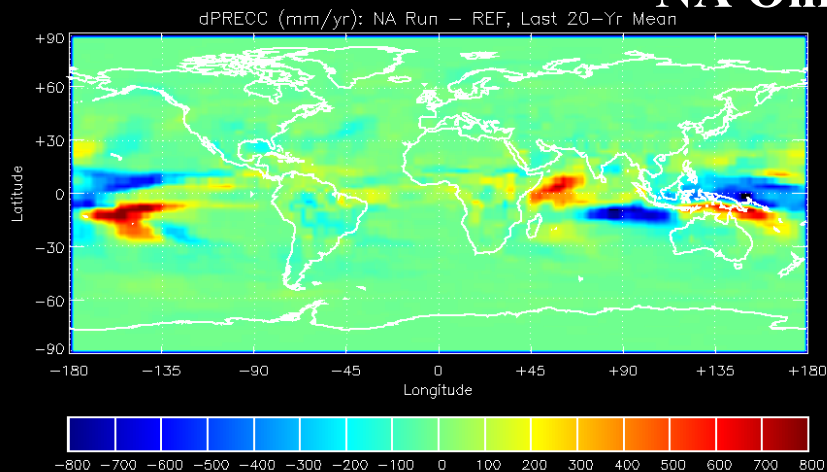
EA Only



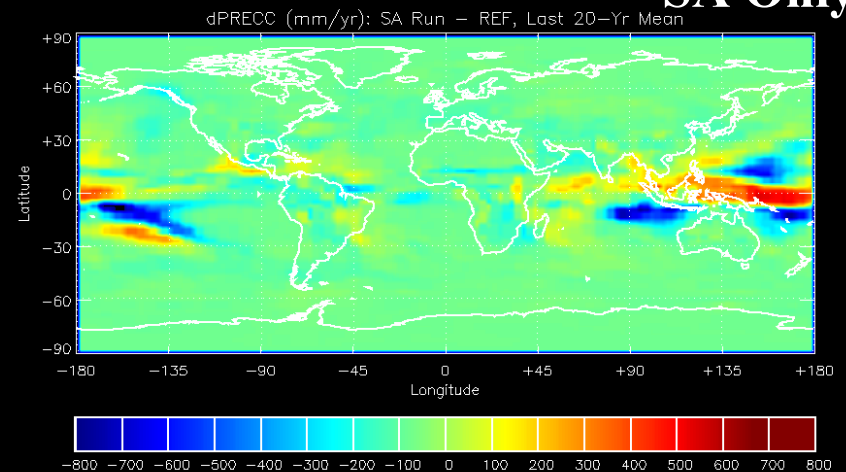
EU Only



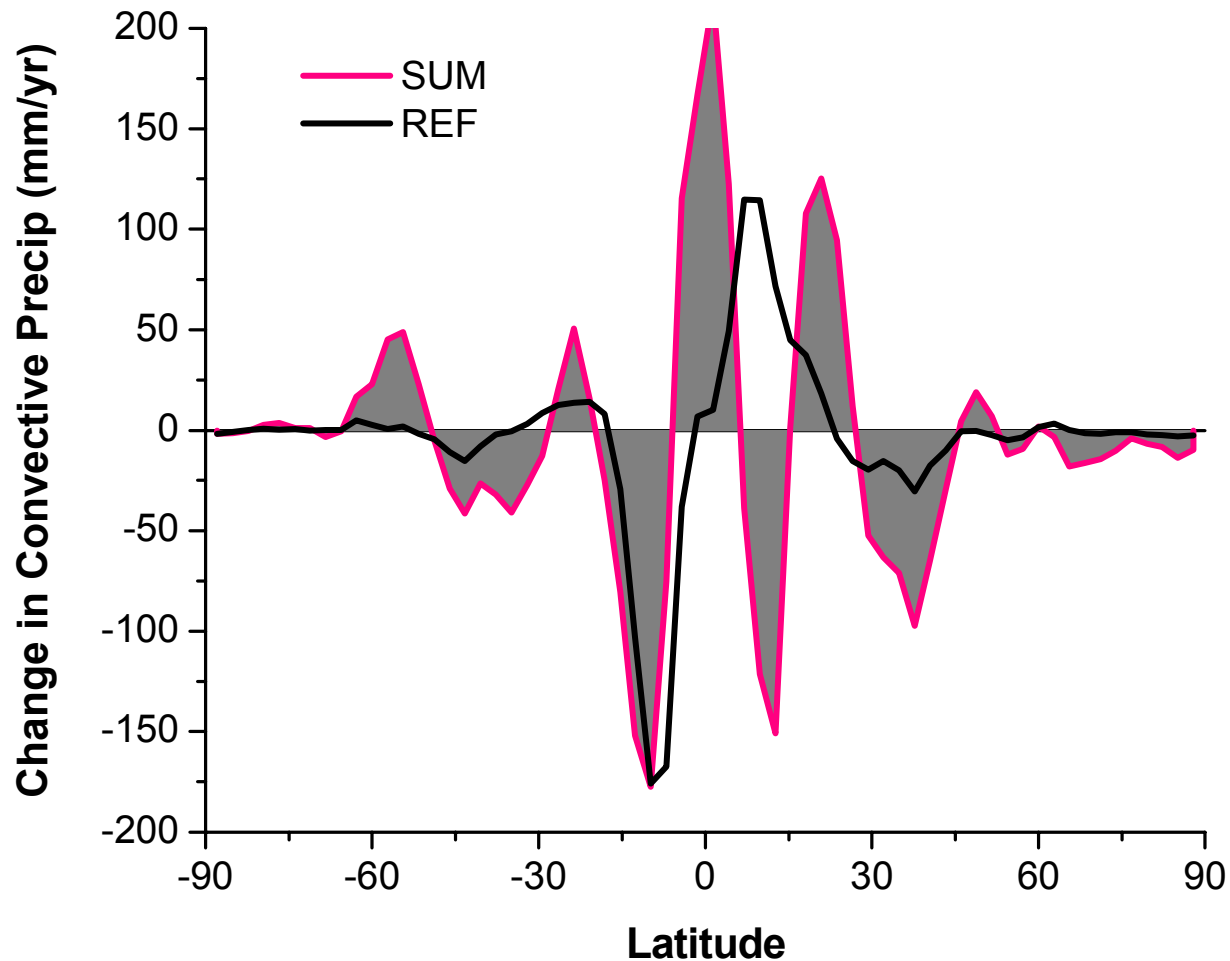
NA Only



SA Only



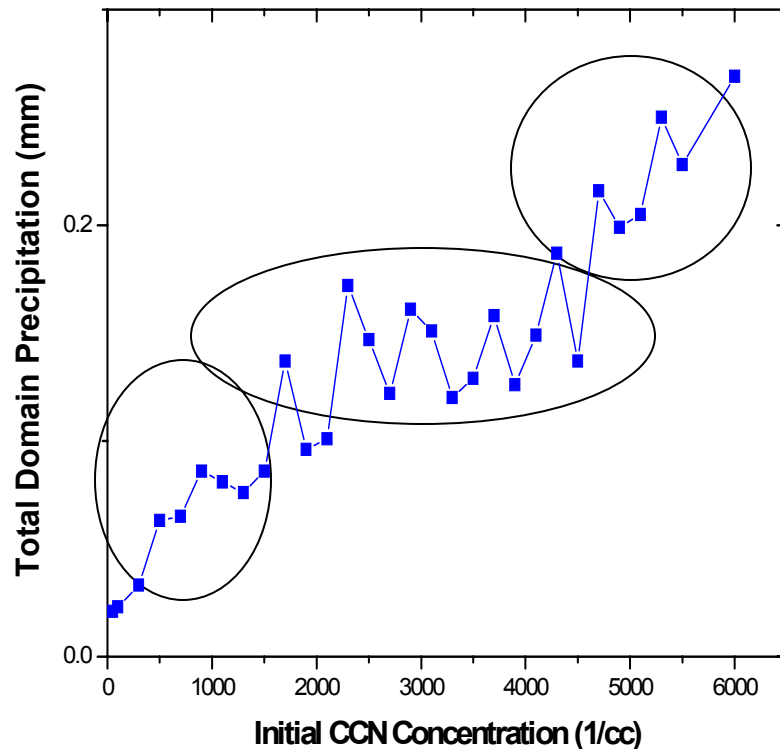
Zonal Mean Changes in Convective Precipitation Change Caused by Regional BC Emissions



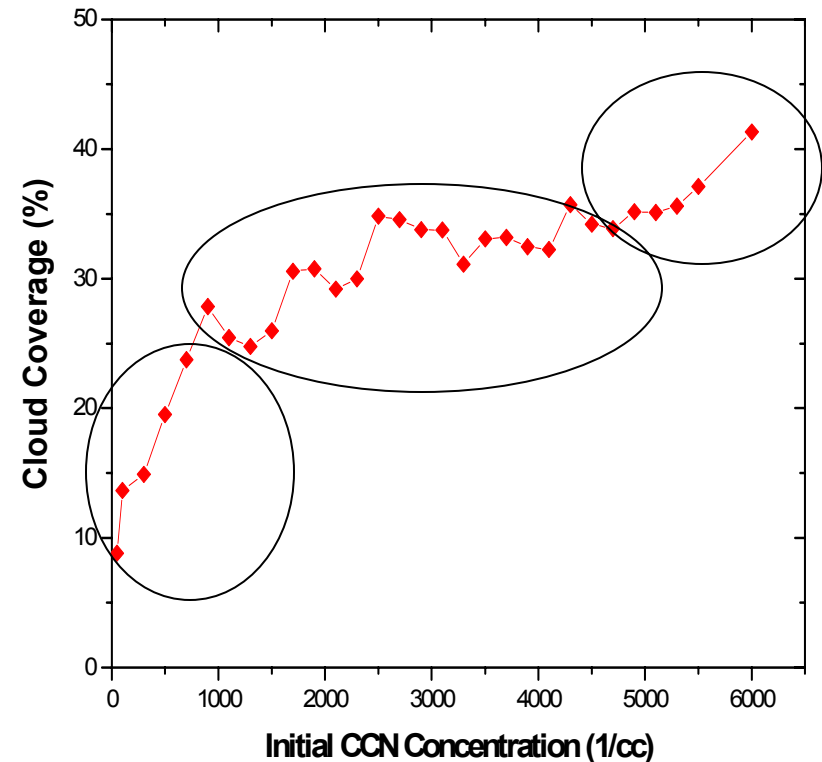
Indirect Effects of BC: The Importance of Process Study

*Results based on 30 3-D cloud-resolving model runs of
a tropical Pacific deep convection case (Wang, 2004a&b)*

Total Precipitation
vs.
Initial CCN Concentration



Maximum Anvil Cloud Coverage
vs.
Initial CCN Concentration



➡ Possible BC Contribution ➡

Summary

- Atmospheric abundance of BC is additively related to the regional emissions (within 5%);
- Emissions from each of the selected major regions can individually (even “remotely”) cause a change in tropical convective precipitation (comparable in magnitude but differing in pattern to the case combining all of them);
- Climate effects of BC emissions from selected regions likely compensate each other over certain areas, particularly in the Northern Hemispheric tropics;
- Limiting emissions of BC in any specific region is unlikely to significantly reduce its global-wide climate impacts.
- Issues for process study: (1) “aged” hygroscopic BC-contained particles and indirect forcing; (2) the role of local thermodynamic effect of absorbing aerosols in the formation of clouds (esp. convective ones) and precipitation.